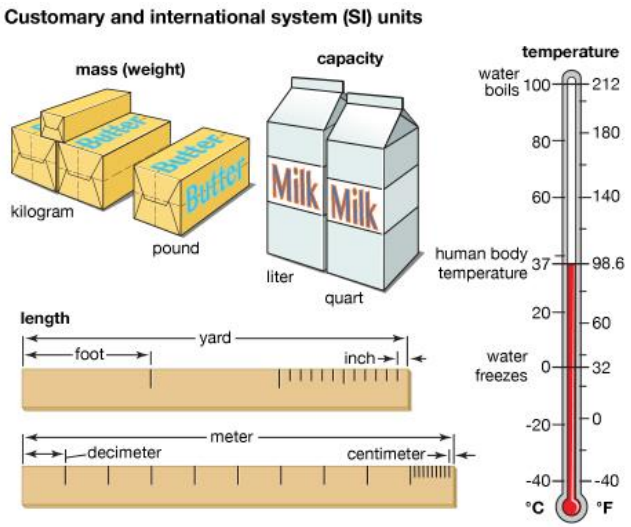
The Metric System

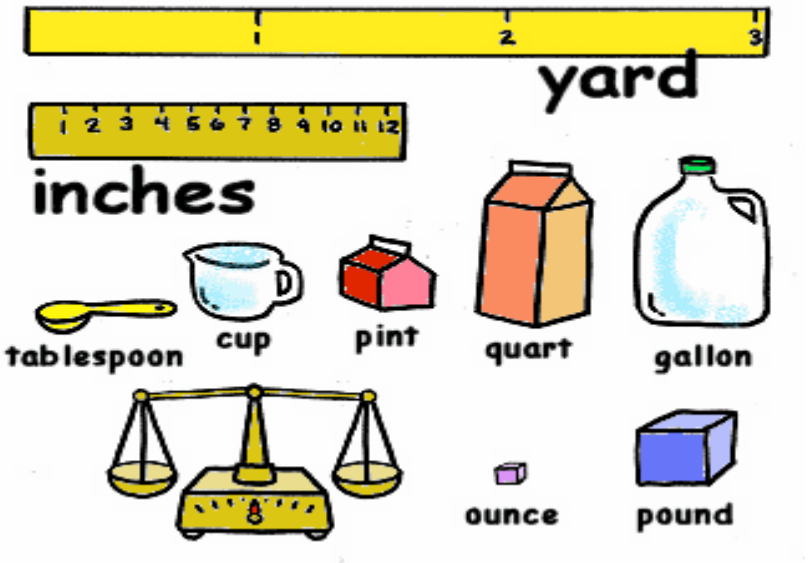


The International System of Units

English Units Based Systems

- **Imperial System of Measurement (British Empire, 1824):**
  - Distance/Length: Inch, foot, yard, mile
  - Volume: fluid ounce, pint, quart, gallon
  - Area: Acre
  - Weight/Mass (three different systems!): grain, ounce, pound, stone, ton

- **US Customary System of Measurement:**
  - Mostly *same unit names*
  - **Units are not identical!** (1 US gal=0.83 imp gal)
  - Different units for liquid and dry measures (liquid/dry ounce)



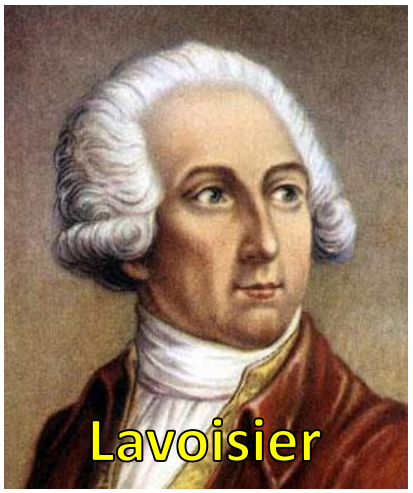
The Metric System

The metric system is an internationally agreed decimal (based on power of 10) system of measurement. It was originally introduced by France in 1799.

Modern **"Metric system"** term is a synonym for **"SI"** or the **"International System of Units" (1960)**—the **official system of measurement** in almost every country in the world.

Origin of the Metric System

- **Idea of standardized system of measurement based on the decimal was first proposed as early as ~1670.**
- **The first practical implementation was carried out by French Revolutionaries towards the end of the 18th century.**
- **In 1790 a committee** (including mathematicians **Laplace** and **Legendre**, and chemist **Lavoisier**) **was appointed to develop a unified, natural, universal system of measurement.**

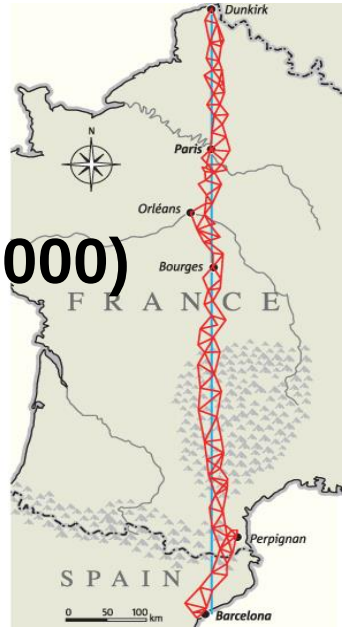


It was called the "metric" system (French for *measure*).

Metric System Basics

- **The metric system** was built around **three base units** that corresponded to a **certain kind of measurement:**
  - **Length = meter**
  - **Volume = liter**
  - **Weight (Mass) = gram**
- **The base units** were derived from the **natural world:** the ***dimensions of the Earth*** and ***properties of water***.
- **Decimal multiplicative prefixes** were added to base units to make up the **full range** of metric system:
  - **milli + meter = millimeter**
  - **kilo + gram = kilogram**
  - **nano + liter = nanoliter**
  - **micro + meter = micrometer**
- Historically, **prototypes** ("originals") of base units were kept in the ***Archives Nationales*** **in France** with **copies manufactured and distributed** among other countries - members of The Metre Convention of 1875 (and subsequent conventions).

Original Definitions



1. **Meter** (length) **- one ten millionth (1/10,000,000) of the quarter of the Earth's meridian*.**

   *determined based on the 1792-1798 survey of the length of the Earth's meridian between Dunkirk (51°N) and Barcelona (41°N) through Paris.

2. **Gram** (mass) **- the mass of one cubic centimeter of water at the melting point of water.**

3. **Second** (time) **- 1/86,400 of a mean solar day; the fraction 1/31,556,925.9747 of the tropical year 1900.**

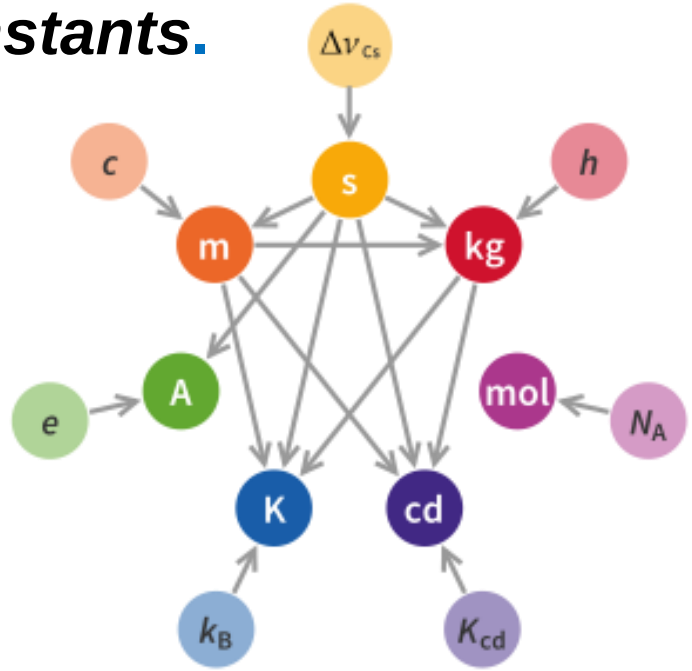
4. **Degree Centigrade** (temperature) - obtained by assigning **0°C to the freezing point of water** and **100°C to the boiling point of water.**

Fundamental SI Units

As Metric System evolved into the **SI system**, **seven mutually independent fundamental units** have been selected:

1. **Meter** (length)
2. **Kilogram** (mass)
3. **Second** (time)
4. **Kelvin** (temperature)
5. **Ampere** (electric current)
6. **Candela** (luminous intensity)
7. **Mole** (amount of elementary entities like atoms or molecules)

On May 20, 2019 all seven have been redefined based on *fundamental physical constants*.



Prefixes in Metric System

Prefix	Symbol	Factor	
tera	T	1000000000000	10^{12}
giga	G	1000000000	10^{9}
mega	M	1000000	10^{6}
kilo	k	1000	10^{3}
hecto	h	100	10^{2}
deca	da	10	10^{1}
(none)	(none)	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	µ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}

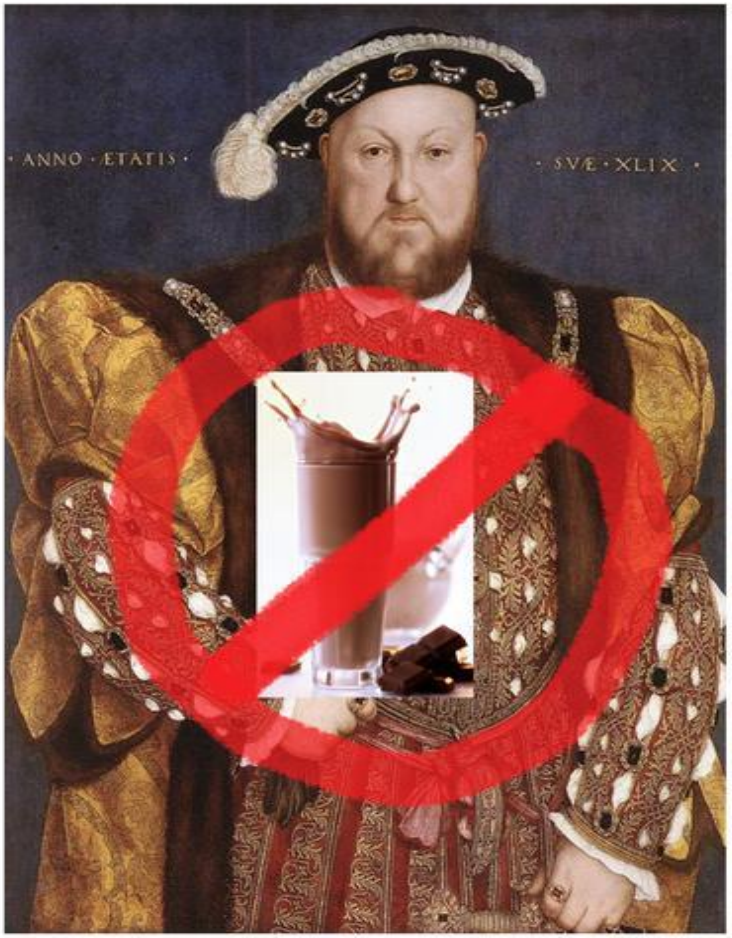
What is the order of the metric system?

- **King Henry Died by Drinking Chocolate Milk**

larger

- King: **Kilo**
- Henry: **Hecto**
- Died: **Deca**
- By: **Base** (m, L, g)
- Drinking: **Deci**
- Chocolate: **Centi**
- Milk: **Milli**

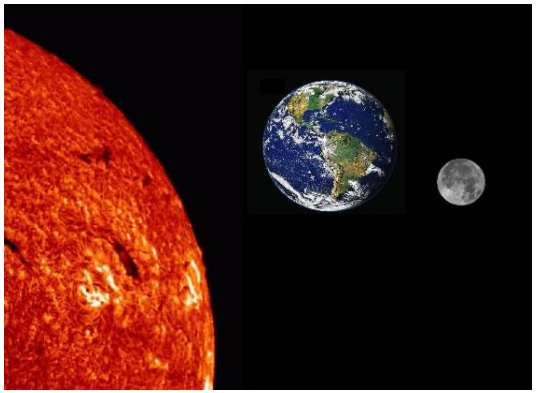
smaller



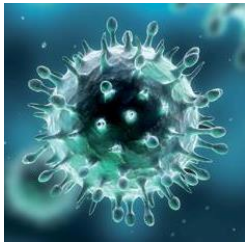
Metric Examples

Any US paper currency note ($1, $5, $10, $20) has a mass of 1 g; the mass of a nickel is 5 g; the mass of a penny is 2.5 grams.

A typical doorknob is ~1 m high.



The mass of the Earth is 6×10^{24} kg; the mass of the Moon is 7.3×10^{22} kg; the mass of the Sun is 1.99×10^{30} kg.

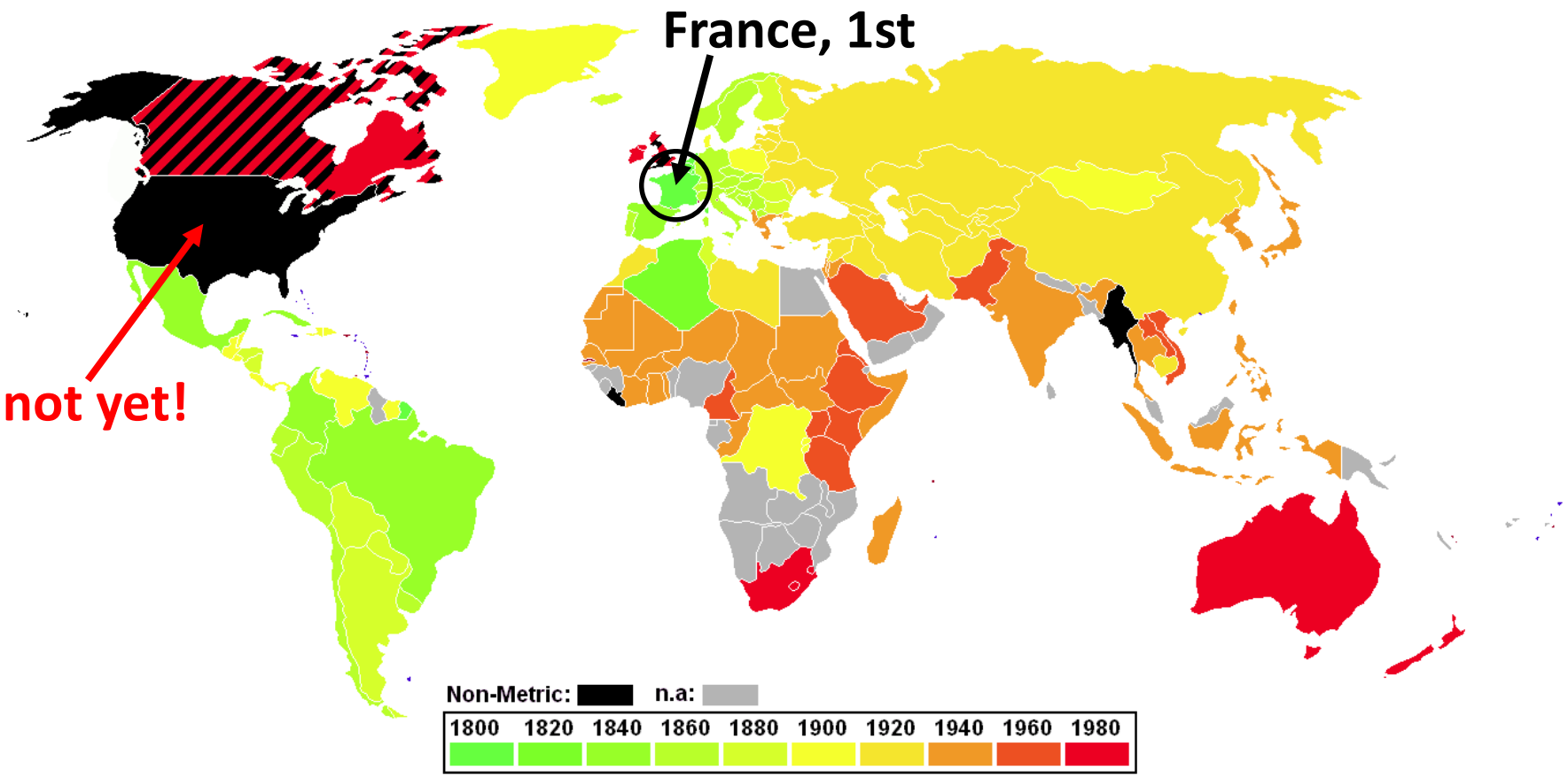


Diameter of Influenza virus is ~20 nm.

The diameter of a CD or a DVD is 12 cm; the diameter of the center hole is 15 mm.

Typical airport runway length is 3.35 km; Boeing 767 jet is 64 m long.

Metrication of the World



Currently USA is the only country (and perhaps also Myanmar and Liberia) **that has not fully adopted the Metric System as its official system of measurement…as a result, Metric System is used in *Science*, but not *Manufacturing*!**

Gimli Glider

July 23, 1983: Air Canada Flight 143 (Boeing 767-233 jet), ran out of fuel at an altitude of 41,000 feet (12 km), about halfway through its flight from Montreal to Edmonton.

The crew were able to glide the aircraft safely to an emergency landing at Gimli Industrial Park Airport. None of the 61 passengers were seriously hurt.

Investigation: fuel loading was miscalculated due to a misunderstanding of the recently adopted metric system which replaced the imperial system.

Loss of NASA orbiter

NASA's Mars Climate Orbiter
lost on September 23, 1999.
Cost: $125 million.

The spacecraft insertion trajectory came too close to the planet; the Orbiter disintegrated upon entering the upper Martian atmosphere.

For a key spacecraft operation, Lockheed Martin engineering team used Imperial units of measurement while the NASA's team used more conventional Metric system…